# SYNOPSIS

**'Underground Water Quality Status of Industrial Areas of Solan (Baddi, Barotiwala, Nalagarh), Himachal Pradesh'**


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Session: 2016-17


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## Introduction:

Water is a universal solvent and as a solvent, it provides the ionic balance and nutrients, which support all forms of life (Rai, 2001). The sustainability of agriculture and the civilization of mankind based on land and water. The three basic needs in human life are food, air and water (Wu-yuan et al., 2010; Yuvaraj et al., 2010). The amount of water on the earth is estimated to be approximately 1388 million billion cubic meters. Only 37.5 billion cubic meter (2.7%) water occurs in the form of fresh water. Of this total fresh water, 8450 thousand billion cubic meter (0.61%) as groundwater and 127 thousand billion cubic meters in the form of lakes, rivers etc (Iqbal and Gupta, 2009). Fresh water is readily available for drinking and other purposes in the form of surface water and ground water. Water is an important source for the industrial and agriculture sectors (Jiang and Zongren, 2012; Senthilnathan et al., 2012). Underground water is the major source for drinking, irrigation and other domestic purpose in both urban and rural areas. In rural areas people are basically dependent on hand pumps for portable water (Verma and Pandey, 2014). Groundwater is generally considered as a safe source of fresh drinking water (Haloi and Sarma, 2011).

Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds. Water pollution affects plants and organisms living in these bodies of water. In all above said cases, not only the individual suffers from the side effects but adverse effects can also be seen in the entire species of individual and due to this the large percentages of population suffer with biological unbalance. Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells). It has been suggested that in worldwide water pollution is a leading cause of death and diseases, it accounts for the deaths of more than 14,000 people daily (West, 2006). Every day, 2 million tons of sewage, industrial and agricultural waste is discharged into the world's water (UNWWAP, 2003). Over 70% of these people who lack sanitation, in which 1.8 billion people, live in Asia. Lack of adequate sanitation contaminates water courses and is one of the most significant forms of water pollution (UNICEF, WHO, 2008). According to the WHO report an access to safe water and sanitation is also a human right, as recognized in 2010 by the United Nations General Assembly (WHO, 2017).

The majorities of the populations in developing countries are not adequately supplied with potable water and are thus compelled to use water from sources like shallow wells and boreholes that renders the water unsafe for domestic and drinking purposes due to high possibilities of contamination from different polluting sources including industrial wastes (AdeJuwan and Mbuk, 2011).

Large scale industrial growth has caused serious concern regarding the susceptibility of underground water contamination due to waste materials. Waste materials near the factories which are subjected to reaction with percolating rain water and reach the aquifer system and hence degrade the groundwater quality (Tyagi et al., 2002). Over exploitation of groundwater also causes depletion of the groundwater level (Jha and Sinha, 2007). The consequences of massive water pollution in relation to health are of great concern because of two third of illness is reported to have been related to the water borne diseases. The water pollution is mainly due to indiscriminate disposal of industrial wastes both on land and other surface water channels. Wells are generally considered as the worst type of ground water sources in the term of physico-chemical contamination due to the lack of concrete plinth and surrounding drainage system (Reza and Singh, 2009). There are various ways as ground water is contaminated such as use of fertilizer in farming, seepage from effluent bearing water body (Adekunle, 2009). Presence of heavy metals in ground water is found in 40 districts from 13 states, viz, Andhra Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, and five blocks of Delhi. In our country, more than 60 percent of the irrigation requirements and 85 percent of drinking water supplies are dependent on groundwater (Gautam and Kumar, 2010).

Every eight seconds, a child dies from water related disease around the globe, 50 percent of people in developing countries suffer from one or more water related disease and 80 percent of diseases in the developing countries are caused by contaminated water (Jagadeesh, 2010). Underground water accounts for 33% of the drinking water for general, industrial and irrigation purposes. Squeezing of underground water by bore well (tube wells and hand pumps) is expected to increase with the increasing population and accelerated pace of industrialization (Ramakrishnaiah et al., 2009). Potable water is the pure quality water that is free from impurities/pathogenic microbes (Lamikaran, 1999; Shittu et al., 2008). It is well

known fact that potable safe water is absolutely essential for healthy living. Adequate supply of fresh and safe drinking water is a basic need for all human beings on the earth. Water Quality Index (WQI) is regarded as one of the most effective way to communicate water quality (Pradhan et al., 2001).

The availability of fresh water determines the location and activities of humans in an area (Oladipo et al., 2011). The anthropogenic discharge represents constant polluting sources and surface runoff is a seasonal phenomenon which is largely affected by climatic conditions. The ground water is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dump causes the ground water to become polluted and creates health problems (Raja et al., 2002).

Water is one of the most vital natural resource of Himachal Pradesh. The underground water resources occur mainly in unconsolidated sediments of inter-montane valleys and in the sub-montane tracts. Human populations of Kangra, Una, Hamirpur, Bilaspur, Mandi, Solan and Sirmaur districts of H.P. largely depend on underground water for potable water requirements. Underground water is squeezed out through open borewells, infiltration galleries and wells. The industrial areas of Himachal Pradesh particularly BBN (Baddi Barotiwala Nalagarh) might be highly Vulnerable to underground water pollution due to industrial effluents.

## Literature Review:

Underground water is used for agricultural, industrial, household, recreational and environmental activities all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. The quality of water get concerned when its physico-chemical and biological characteristics found deteriorates and becomes harmful to human being. The contamination of the water bodies occurs when pollutants are directly and indirectly discharged in to the water without adequate treatment to remove harmful compounds (FWPCA, 1968).

The potential toxic metal elements such as chromium, lead, copper, zinc etc., are identified to cause health hazards in animals was reported (Lowe, 1970).

The heavy metals such as cadmium, lead, mercury and arsenic have the capacity to affect adversely the activity of a living organism, growth, health, life span, and reproduction performance was reported (Perry et al., 1974).

The quality of 981villages for ground water sources in Ajmer, Rajasthan were analysed and found that water of about 69% villages falling in acceptable flouride limit and waters of 109 villages were in need of deflouridation were demonstrated (Bhargava et al., 1978).

It was found that 49% of the ground water sources in semiarid tract of Agra contained more than 1 mg/litre of fluoride, hence the water was not potable. If 10 mg/litre of fluoride is considered as a safe value for common crops then 23% of waters contained injurious level of fluoride was reported (Murty, 1986).

Rao et al., 1986 analysed samples from dug wells and borewells in Nuzvid town of Andhra Pradesh. They concluded from their studies that the waters from bore wells were better than to dig wells was reported.

The study on the impact of seasonal variations on the physico-chemical characteristics of water resources quality in the western horn of the Niger Delta region of Nigeria has been investigated. The investigations were on open well and borehole water. The pH of the water resources is acidic in nature with pH values < 5.50 at all seasons. The physico-chemical water quality parameters examined in the three water resources are either above or below the target water quality range (TWQR) for domestic use, making these three water resources available in the area a potential health hazards to inhabitant (Efe et al., 2005).

It was studied that improper and open drainage system may cause percolation of undesirable materials and contaminate the underground water. The pH of water at Gajanan nagar, Sahakar Nagar and New RMS Colony was towards higher side but was within the normal limits, TDS value of water was highest at Timber Market with high Chlorides and COD. Conductivity of water was maximum, Calcium value were above ISI levels at Kandari,New RMS colony, Swamisamarth, Anand nagar and Mohi nagar but magnesium levels at all sites were within the normal range (Phalak et al., 2006).

The study on ground water pollution at Mettupalyam taluk, India was performed and found that continuous disposal of industrial effluent on land which has

limited capacity assimilating to the pollution load has led to ground water pollution was reported (Mukarjee and Nelliyat, 2006).

Nassef et al., 2006 assessed the heavy metal concentration in the soil and the groundwater of Sadat City in Egypt and its influence due to the highly developed industrial activities in that area. The levels of Pb, in the ground water wells are reportedly above the Egyptian and the WHO guide lines in three wells in the industrial area.

The study on the impact of industrialization on groundwater quality in Peenya industrial area reveals that most of the study area is highly contaminated due to the excessive concentrations of one or more water quality parameters such as nitrates, total hardness, calcium, magnesium, total dissolved solids, sulphates and fluorides, which have rendered nearly 77% of the water samples tested, non- potable was reported (Shankar et al., 2007).

The study of Dhakate and Singh, 2008 revealed the impact of pollutants in ground water due to opencast chromium mining in Sukinda valley, Orissa, India and has found high level of TSS, Cu, Fe and Cr in groundwater by this investigation.

The study on the influence of seasonal changes on the properties of the borehole water in Abraka Ethiope east LGA Delta state, Nigeria. Samples from seven representative quarters in Abraka Township were collected and assessed for both dry and wet seasons. The values of the various parameters were as follows: pH 6.3 to 7.1 for dry season and 6.2 to 8.00 for wet season; conductivity 62 to 84 µs/cm for dry season and 57 - 67 µs/cm for wet season; total suspended solids (TSS) 7.21 to 12.11 mg/L for dry season and 11.33 to 14.30 mg/L for wet season; total dissolved solids (TDS) 0.0 to 2.11 mg/L for dry season and 0.39 to 7.11 mg/L for wet season; biological oxygen demand (BOD) dry season 1.44 to 2.68 mg/L for dry season and 0.26 to 1.53 mg/L for wet season. The values for the trace metals and other parameters were within the WHO permissible limit for drinking water. The water is therefore portable was reported (Agbaire and Oyibo, 2009).

The investigation of ground water as well as surface water quality and physico-chemical characteristic of Bargarh district of Orissa, India was performed and present work has been conducted by monitoring two types of ground water i.e. dug well water and bore well water of 10 wards of the town as well as three types of

ponds. Various parameters like Temperature, pH, Total suspended solids, and Total dissolved solids, Alkalinity, Dissolved oxygen, Chemical Oxygen Demand, Nitrate, Chloride, Sodium, Potassium, Fluoride etc. give a picture of quality parameter in both dug well and bore well water as well as pond water of the town. By observing the result it can be concluded that the parameters which were taken for study the water quality are below the pollution level for ground water which satisfy the requirement for the use of various purposes like domestic, agricultural, industrial etc. But in case of surface water, the water qualities of small community pond are above the permissible limit (Mahananda et al., 2010).

It was studied that heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria and found that when compared to the limits set by WHO for drinking water, heavy metals with the exception Cu were higher than the limits by recent investigations (Adelekan and Adekunle, 2011).

The study was carried out to assess the impacts of industrial activities on the ground water quality in and around SIPCOT Industrial complex in Cuddalore District. The quality was assessed in terms of physico- chemical parameters. Ground water and municipal water samples were collected from seven villages in cuddalore Taluk during December 2010 to February 2011. By investigation, it was found that the underground water was contaminated at few sampling sites. The remaining sampling sites shows physic-chemical parameters within the water quality standards and the quality of water is good and it is fit for drinking purpose was reported (Devi and kumar, 2012).

Sirajudeen et al., 2013 carried out the work on ground water for evaluating the W.Q.I. Samples collected from Ampikapuram area near Uyyakondan channel Tiruchirappalli district. The WQI for samples ranged between 244 to 383.8. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination.

The results of Solanki et al., 2013 and Solanki and Gupta, 2013 shows seasonal variation and physico–chemical study of surface water and underground water of Rewa District, Madhya Pradesh state and indicated the overall alkaline nature. The pH of river water and underground water lies between desirable limit.

Samples have Total dissolved solid less than 1000 mg/l, hence suitable for drinking and also samples have normal carbonate and normal sulphate. The comparison study of analyzed data with World health organization (WHO), Bureau Of Indian Standard(BIS) and Indian Standards Institution (ISI) desirable limit for drinking water indicated that all water are more or less suitable for drinking by these investigations.

Ground water samples of bore wells (BW), open wells (OW), and Hand Pumps (HP) were collected from different locations in Chrompet in Kanchipuram District, Tamil Nadu and were analyzed for their physico-chemical characteristics. The ground water samples were studied during pre-monsoon (July-September 2013) and post monsoon (January 2014) seasons from sixteenth different places. The present study was undertaken to characterize the physico-chemical parameters such as pH, Electrical Conductivity (EC), Calcium Hardness (CH), Magnesium Hardness (MH), Total Hardness (TH), Bicarbonate ($HCO_3^-$), Chloride ($Cl^-$), Sulphate ($SO_4^{2-}$), Sodium (Na), Potassium (K) Total Dissolved Solids (TDS). Each parameter was compared with its standard permissible limit as prescribed by World Health Organization (WHO). The Water Quality Index (WQI) was calculated and it reflected that 12.5% of the samples were of good quality in pre monsoon, 75% of samples were poor quality and 12.5% of samples were of very poor quality in pre monsoon and in post monsoon 44% of samples were of poor quality and 56% of samples were of very poor quality was reported (Karpagam and Ramesh, 2015).

The present study was carried out to determine the seasonal variations of physic-chemical parameters in water samples from Antiya Taal, Jhansi city, India during August 2014 to May 2015. Seasonal variation of some physico-chemical parameters such as, temperature, pH, salinity, turbidity, conductivity, hardness, chloride contents, alkalinity, total solid, total suspended solid, total dissolved solid , free CO2, dissolved oxygen (DO), chemical oxygen demand(COD), biological oxygen demand (BOD) and heavy metals were determined for the estimation of pollution load. The water of Antiya Taal was found better in the month of November and February compared to that of the month of May (Sharma and Singh, 2016).

This study was carried out to assess the groundwater quality of Aligarh city. Forty groundwater samples were collected during pre and post-monsoon period of the year 2013 and analyzed for physic-chemical parameters such as electrical conductivity, pH, total dissolved solids, calcium, magnesium, chloride, sulfate,

fluoride, heavy metals etc. The results are compared with the specifications prescribed by the Bureau of Indian standards. It is revealed that concentration of magnesium, total hardness, alkalinity, cadmium, Iron, pH, lead, TDS, calcium, copper, sulfate, chloride, manganese and chromium is higher than the permissible limit prescribed by the Bureau of Indian standards. It indicates signs of water quality deterioration. So, it is necessary to take rational steps to manage water in this region before it becomes a crisis, as this will affect the economy and will also lead to various water-borne diseases (Khwaja et al., 2016).

The ground water sample from Pydibhimavaram industrial area was assessed for their quality in terms of their potential for drinking and irrigation. The results revealed that the ground water in the study area was neutral. The results indicated that all the samples have high electrical conductivity. The results also showed that in some areas chlorides, hardness, sulfates and nitrites concentrations were above the permissible limits. Samples of the Pydibhimavaram Industrial area exceed the permissible limits of BIS. The elemental concentrations of Fe, Ni, Cd, and Pb were found to exceed the permissible limits of drinking water quality, whereas Zn concentrations are within the permissible limits. High trace metal concentrations were observed in ground water samples of Pydibhimavaram industrial area. This research may serve as a preliminary study to provide baseline information that may direct future water quality assessment studies in the study area was reported (Rao and Kalpana, 2016).

A comprehensive study on distribution pattern of fluoride content and some of physico- chemical parameters of ground water quality analysis in chittapur & Aland taluka around the six selected villages is extensively monitored for 12 months from july 2014 to june 2015. Bore wells from different areas were selected for sampling and collected samples were analyzed for physico-chemical parameters and majorly fluoride content was found in the ground water. The study revealed that, the naturally occurring fluoride contamination in ground water of study area is more wide spread than in generally recognized. This study has been showed a higher flouride 2.2ppm not in the permissible limits; chloride 355 .42 mg/l; alkalinity values is 562 mg/l; pH value is within the permissible limit 6.5 to 7.2; TDS value is  in the month of April to may it increases its values 580 to168 mg/l; DO in the month of January to a maximum of 8.57 mg/l in the month of may; TH the mean values of TH is 343.55 mg/l its very

hard category > 300 mg/l 11) calcium 220 mg/l its cross the permissible limits; Magnesium 66.20 mg/l so that the water samples in the all the months are not in the under permissible limits. (Choudhary and Naik, 2017)

The study of Manohar et al., 2017 assessing the groundwater quality along the Vrishabhavathi river basin for various water quality variables and revealed that majorly $Ca^{++}$ and $Mg^{++}$ are the dominant cations and $HCO^{3-}$ and $Cl^{-}$ are the dominant anions in samples. Statistical measures such as Mean, SD, SE of sample means, coefficients of Skewness and Kurtosis have been computed using the statistical package to assess the characteristics of the selected water quality variables. Further, 95% confidence intervals have been obtained for the true means of these variables and water quality variables crossing the permissible limits of WHO.

The review of literature reveals that, there are no scientific studies on the physico-chemical properties and quality status of underground water in and around BBN industrial area. So the present investigations will focus on underground water quality status of industrial areas of Baddi (Himachal Pradesh), India.

## Research Gap identification:

It is evident from the literature review that managing water is growing concern to all the countries in the world and countries are starting to face challenges regarding water supply and need to update aging water treatment and delivery systems, sometimes referred to as water infrastructure (WHO, 1999; WHO, 2008). Pollution of underground water due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters in India. Shallow aquifer in Ludhiana city, the only source of its drinking water, is polluted by a stream which receives effluents from 1300 industries. Excessive withdrawal of groundwater from coastal aquifers has led to induced pollution in the form of seawater intrusion in Kachchh and Saurashtra in Gujarat, Chennai in Tamil Nadu and Calicut in Kerala (Kumar and Shah, 2006).

Due to recent industrialization and ever increasing urbanization, the quality of groundwater has become a matter of major concern mainly because of heavy metal contamination. Contamination of water by trace metals is a serious health issue (Aiyesanmi et al., 2004; Calderon, 2000). Contamination of water by trace metals is a

serious health issue. Studies have shown that heavy metal toxicity leads to cardiovascular, neurological and renal problems (Vallee and Ulmer, 1972). Solan is one of the south-western districts of Himachal Pradesh having geographical area of 1,936 $km^2$. Large and small scale industrial development has taken place randomly all over the district. The Baddi Barotiwala Nalagarh (BBN) area which is about 35 Kms long consists of 21 Panchayats and 115 villages. The industrial belt of BBN was chosen as target area to assess the status of industrial pollution on underground water quality as this area has boomed with much industrial developments in the last few decades. The study on underground water in this area is not done.

This study will help in proper management of underground water resources and further help to curtail deterioration of water quality in the study area. In view of this, present work needs to be undertaken.

## Proposed Objectives:

This present work is undertaken with following objectives:

1. To investigate the Physico-Chemical characterization of underground water.
2. To check the quality status of underground water.
3. To suggest some recommendations for the conservation and improvement of water quality.
4. To study the impact of seasonal variation on physico-chemical parameters.

## Proposed Methodology:

Physico-chemical studies on underground water at Baddi Barotiwala Nalagarh (BBN) areas of H.P. will be carried at different sampling points. This study will be carried out for one year. Samples will be collected from eight sampling stations for the analysis of physico-chemical parameters.

1. **Sampling Stations:** Sampling stations will be selected on the basis of the identified pollution sources to assess the underground water quality. Sampling stations will cover mostly locations affected by the industrial wastages. The representative samples of the particular area will be checked with the analysis to reflect the status of underground water. On the basis of above criteria following eight sampling points will be selected. All the sampling stations have depth

ranging from 65 o 140 Meters. The location and description of the sampling points are as follows:

***1.1 SUW-1 (First Sampling Station of underground water):*** It is a bore well located at Katha village in Baddi at Altitude- 450m, Lat.-30.938485$^0$ N and Lng.-76.81439$^0$ E.

**Figure 1: SUW-1 bore well located at Katha village in Baddi.**

*1.1.1 Pollution Sources:* Sampling station chosen on the basis of industrial wastages released openly nearby the sampling station which shown in the figure 2. Nearby industries, which manufacture personal care & Cosmetic products etc. Chemicals released by these industries may contaminate the underground water.

**Figure 2: Pollution Sources near first sampling station SUW-1.**

***1.2 SUW-2 (Second Sampling Station of underground water):*** It is a hand pump located at left side of main bazaar of Manpura, Baddi at Altitude-380m, Lat.-30.964235° N and Lng.-76.769295° E.

**Figure 3: SUW-2 hand pump located at Manpura Bazar in Baddi.**

*1.2.1 Pollution Sources:* Sampling station chosen on the basis of industrial wastages released openly nearby the sampling station which was shown in the figure 4. Nearby industries, which manufacture pharmaceutical liquid, tablets and capsules etc. Chemicals released by these industries may contaminate the underground water sources of surrounding areas.

**Figure 4: Pollution Sources near second sampling station SUW-2.**

***1.3 SUW-3 (Third Sampling Station of underground water):*** It is a borewell located at Thana in Baddi at Altitude-410m, Lat.-30.962338$^0$ N and Lng.-76.791353$^0$ E.

**Figure 5: SUW-3 bore well located at Thana in Baddi.**

*1.3.1 Pollution Sources:* This sampling station was chosen on the basis of industrial wastages released openly nearby the sampling station which shown in the figure 6. Nearby industries, which manufacture packaging bottles, jars and goods etc. Chemicals released by these industries may contaminate the underground water sources.

**Figure 6: Pollution Sources near third sampling station SUW-3.**

***1.4 SUW-4 (Fourth Sampling Station of underground water):*** It is a handpump located at Jharmagri chowk, Baddi at Altitude -426m, Lat.-30.929478$^0$ N and Lng. -76.826181$^0$ E.

**Figure 7: SUW-4 hand pump located at Jharmagri chowk.**

*1.4.1 Pollution Sources:* Sampling station chosen on the basis of industrial wastages released openly nearby the sampling station which shown in the figure 8. Nearby industries, which manufacture cough syrup,injection& building materials etc. Chemicals and waste materials released by these industries may contaminate underground water.

**Figure 8: Pollution Sources near fourth sampling station SUW-4.**

***1.5 SUW-5 (Fifth Sampling Station of underground water):*** It is a borewell located backside of Maclod Company Theda in Baddi at Altitude 362m, Lat.-30.992667$^0$ N and Lng.-76.752113$^0$ E.

**Figure 9: SUW-5 borewell located at Theda in Baddi.**

*1.5.1 Pollution Sources:* Sampling station chosen on the basis of industrial wastages released openly nearby the sampling station which shown in the figure 10. Nearby industries, which manufacture air conditioner, electric and electronic goods etc. Chemicals released by these industries may contaminate underground water.

**Figure 10: Pollution Sources near fifth sampling station SUW-5.**

***1.6 SUW-6 (Sixth Sampling Station of underground water):*** It is a borewell located at Khera near colony building at Altitude-340m, Lat.-31.012389$^0$ N and Lng.76.72279$^0$ E.

**Figure 11: SUW-6 borewell located at Theda in Baddi.**

*1.6.1 Pollution Sources:* Sampling station chosen on the basis of industrial which manufacture thread, laces& polyester etc, which release chemicals and wastages openly nearby the sampling station which shown in the figure 12. Nearby industries, which manufacture electric and electronic goods and cosmetic materials etc. Chemicals released by these industries may contaminate underground water.

**Figure 12: Pollution Sources near sixth sampling station SUW-6.**

***1.7 SUW-7 (Seventh Sampling Station of underground water):*** It is a borewell located at Lodhi Majra industrial area of Baddi at Altitude-395m, Lat.-30.99175$^0$ N and Lng.-76.77482$^0$ E.

**Figure 13: SUW-7 borewell located at Lodhimajra in Baddi.**

*1.7.1 Pollution Sources:* Sampling station chosen on the basis of industrial wastages released openly nearby the sampling station which shown in the figure 14. Nearby industries, manufacture printing paper, paper roll printing& coated book printing. Chemicalss and waste material released by these may contaminate underground water sources of surrounding areas.

**Figure 14: Pollution Sources near seventh sampling station SUW-7.**

***1.8 SUW-8 (Eighth Sampling Station of underground water):*** It is a borewell located at Manpura at Altitude-370m, Lat.-30.98918$^0$ N and Lng.-76.751434$^0$.

**Figure 15: SUW-8 borewell located at Manpura in Baddi.**

*1.8.1 Pollution Sources:* Sampling station chosen on the basis of industrial wastages released openly nearby the sampling station which shown in the figure 16. Nearby industries manufacture pharmaceutical capsule, drug& tablets etc. Chemicals and other waste materials released by these may contaminate underground water.

**Figure 16: Pollution Sources near eighth sampling station SUW-8.**

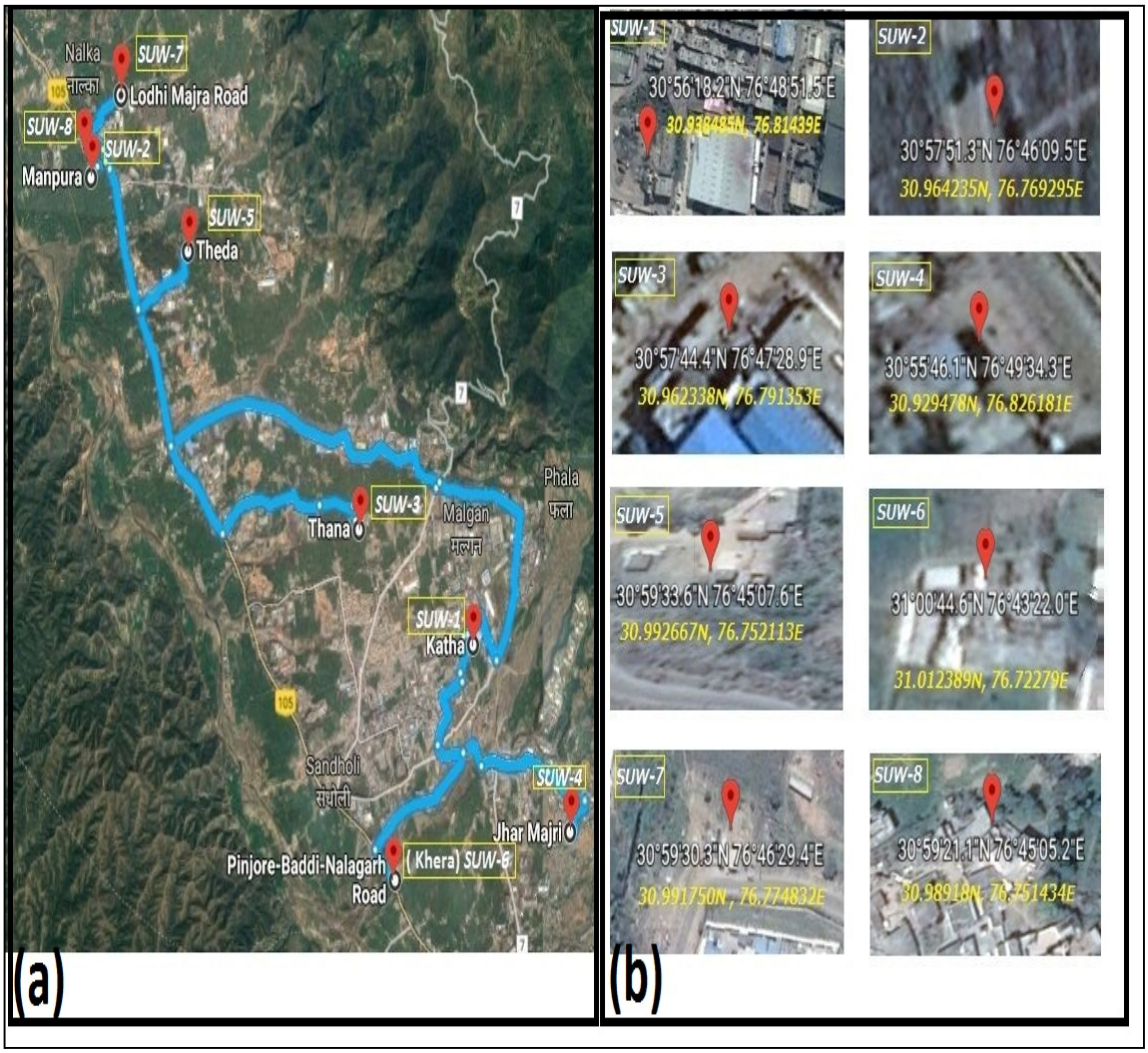



**Figure: 17(a) Google earth locations of sample stations, (b) Longitude and latitude position of sample stations with codes.**

**2. Sampling Programme:** Underground water samples will be collected from eight sampling stations for two years. Samples will be collected from eight sampling stations for the analysis of physico-chemical parameters.

**3. Sampling Procedure:** The samples of underground water will be collected from bore wells and hand pumps near the industrial areas of BBN, where the industrial wastages released openly and stored in clean pre rinsed polythene bottles.

**4. Parameters to be analyzed:** The Physico-chemical parameters of water will be analyzed by standard methods for the Examination of Water and Wastewater devised by American Public Health Association, 2012 (Rice et al.,2012). The various parameters employed for analysis of underground water under present study will be as follows:

**Table 1: List of physico-chemical parameters employed for the analysis of underground water at different selected sampling stations.**

| Sr. No. | Parameters | Method |
|---|---|---|
| **1.** | Alkalinity (as $CaCO_3$) mg/L | Titration Method (APHA 22"$^{d}$ Ed.- 2320 B] |
| **2.** | Biological Oxygen Demand (BOD) mg/L | 3-Day BOD Test (APHA 22$^{nd}$ Ed.- 5210 B) |
| **3.** | Calcium Hardness mg/L | EDTA Titrimetric Method (APHA 22"$^{d}$ Ed.- 3500 B) |
| **4.** | Chemical Oxygen Demand (COD) mg/L | Nomagraphic Determination (APHA 22$^{nd}$ Ed.- 4500-$CO_2$) |
| **5.** | Chloride (as $Cl^-$), mg/L | Argentometric Method (APHA 22$^{nd}$ Ed.- 4500B) |
| **6.** | Copper (as Cu) mg/L | Atomic Abosrption Spectrophotometric (AAS) |
| **7.** | Iron (as Fe) mg/L | Phenanthroline Method (APHA 22$^{nd}$ Ed.- 3500-Fe B) |
| **8.** | Lead (as Pb) mg/L | Atomic Absorption Spectrophotometric (AAS) |
| **9.** | Mercury (as Hg) mg/L | Atomic Absorption Spectrophotometric (AAS) |
| **10.** | Magnesium Hardness | By Calculation (APHA 22$^{nd}$ Ed.- 3500 B) |
| **11.** | Nitrate (as$NO_3^-$) mg/L | Ultraviolet Spectrophotometric Screening Method (APHA 22$^{nd}$ Ed.- 4500-N0$_3$-B] |
| **12.** | Ph | pH Meter Method |
| **13.** | Temperature | Thermometer Method |
| **14.** | Total Hardness mg/L | EDTA Titrimetric Method (APHA 22"$^{d}$ Ed.- 2340 B) |
| **15.** | Total Dissolved Solids mg/L | TDS Method (APHA 22"$^{d}$ Ed.- 2540 C) |
| **16.** | Turbidity | Nephelometric Method (APHA 22»$^{d}$ Ed.- 2130 B) |
| **17.** | Colour | Visual Comparison Method (APHA 22"$^{d}$ Ed.- 2120 B) |
| **18.** | Odour | Threshold Odor Test (APHA 22"$^{d}$ Ed.- 2150 B) |

| | | |
|---|---|---|
| **19.** | Fluoride | Ion Selective Electrode Method (APHA 22"d Ed.- 4500-F C) |
| **20.** | Sodium | Flame Emission Photometric Method (APHA 22nd Ed.- 3500-Na B) |
| **21.** | Cadmium | Atomic Absorption Spectrophotometric (AAS) Method |
| **22.** | Zinc | Atomic Absorption Spectrophotometric (AAS) Method |
| **23.** | Manganese | Atomic Absorption Spectrophotometric (AAS) Method |
| **24.** | Sulphate | Capillary Ion Electrophoresis Method (APHA 22"d Ed.- 4140) |
| **25.** | Boron | Curcumin Method (APHA 22"d Ed.- 4500 B) |
| **26.** | Ammonia | Titrimetric Method (APHA 22"d Ed.- 4500) |

The Water Quality Index (WQI) is calculated by using the expression given in following Equation:

$$WQI = \text{™} \sum qn\ Wn / \sum Wn$$

Where; qn = Quality rating of $n^{th}$ water quality parameter;

Wn= Unit weight of $n^{th}$ water quality parameter.

The ranges of WQI, the corresponding status of water quality and their possible use are summarized in table given below:

**Table 2: Water Quality Index values and their possible uses.**

| Sr. No. | WQI Value | Status | Possible Usages |
|---|---|---|---|
| 1 | 0-25 | Excellent | Drinking, Irrigation and Industrial |
| 2 | 25-50 | Good | Domestic, Irrigation and Industrial |
| 3 | 51-75 | Fair | Irrigation and Industrial |
| 4 | 76-100 | Poor | Irrigation |
| 5 | 101-150 | Very poor | Restricted use for Irrigation |
| 6 | Above 150 | Unfit for Drinking | Proper treatment required before use |

## Thesis Outline:

Thesis will comprise five chapters as:

**Chapter I (Introduction)** includes the detail of water, its availability, its correlation with health and population growth, water system, underground water and their pollution problems, need of study and objectives of the study.

**Chapter II (Literature Review)** gives detailed review of published literature with reference to water resources and systems, water pollution, water pollution scenario of India and Himachal Pradesh with specific references to the underground water in India & Himachal Pradesh.

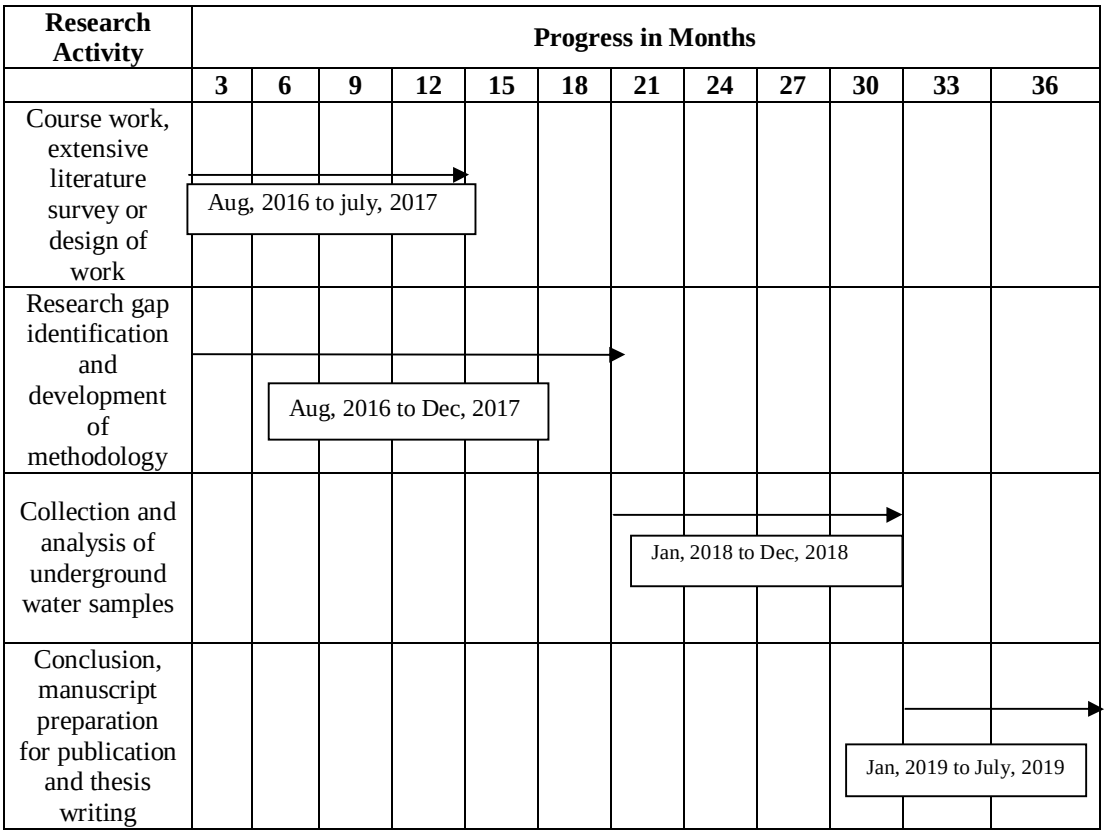
**Chapter III (Material and Methods)** includes the required materials and methodology adopted for carrying out present investigation. Methods used and equipment utilized are described in detail. The sampling techniques, sampling stations selection and criteria of selection of sampling stations are explained in detail.

**Chapter 4 (Results and Discussion)** includes the detailed results obtained and will be presented in tabular form with statistical operations as mean (average), maximum value, minimum value and standard deviation. The results are also presented in graphic form. It also includes explanation of results of Physico-chemical properties giving sampling stations variation, seasonal variation and their correlation with findings of other researches.

**Chapter 5 (Conclusion and Recommendations)** includes brief and concise summary of the results. It also gives the scope of various measures which can be adopted as remedial measures. It also illustrates scope of further research on the basis of recommendations.

## Research Plan Schedule:

The research plan schedule of proposed research titled "Underground Water Quality Status of Industrial Areas of Solan (Baddi, Barotiwala, Nalagarh), Himachal Pradesh" is as under.

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